

International Journal of Aquatic Research and Education

Volume 11

Number 4 *Selected Papers from 2018*

*Lifesaving Foundation Drowning Prevention and
Rescue Research Conference*

Article 2

5-31-2019

The Consequences of Cold Water Immersion: Impacts and Treatment

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Recommended Citation

Buck, Patrick J. Ph.D.; Roberts, Commander William; and Minehane, Commander Ken (2019) "The Consequences of Cold Water Immersion: Impacts and Treatment," *International Journal of Aquatic Research and Education*: Vol. 11 : No. 4 , Article 2.

DOI: 10.25035/ijare.11.04.01

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The Consequences of Cold Water Immersion: Impacts and Treatment

Cover Page Footnote

Research undertaken at the Irish Naval base, Haulbowline, Ringaskiddy, County Cork. Appreciation to the ten volunteers who participated in the cold water immersion.

Abstract

This paper documents a demonstration project conducted by the authors under the auspices of the Irish Naval service. It explores and describes in detail the consequences that cold water immersion can have on the human body. Further, this study investigates post immersion treatment and survival challenges and proposes appropriate casualty care regimes with specific focus on 'post rescue collapse' and 'afterdrop.' Observations of individual differences in response are reported.

Keywords: cold water immersion, hypothermia, drowning prevention, post rescue collapse, after drop

Introduction

Cold water immersion is a potential hazard for all water users. While much of the applied and academic research has focused on class D (continental/microthermal) and class E (polar and alpine) climates (Köppen climate classification system), the consequences of being immersed in waters (sea/inland) in North Western Europe (temperate oceanic climate (class C)), that include the waters in and around Ireland and the United Kingdom, can similarly have serious outcomes for a casualty.

This research programme was conceived primarily as a demonstration project and training exercise. Its principle aims were;

Part 1: to demonstrate the incapacitating effects of cold water immersion;

Part 2: to demonstrate the requirements for correct casualty extraction techniques and post immersion casualty care;

Part 3: to demonstrate the effects of Post Rescue Collapse (PRC) and 'afterdrop;'

Part 4: to demonstrate the importance of wearing a personal floatation device (PFD);

and

Part 5: to produce a training video to demonstrate the effects of cold water immersion and cold water immersion casualty treatment protocols.

Method

Location and Participants

This project was conducted at the Irish Naval Service Base, Haulbowline, Ringaskiddy, County Cork in 2015. On Tuesday 19th May 2015, ten medically screened Irish Naval volunteers, both male and female, entered the waters at the South Wall Pontoon, Naval Basin, Haulbowline, Cork Harbour. The sea water temperature was 11.6° C. The weather conditions were variable with blustery north westerly winds. Sea conditions were calm in the Naval Basin (appendix 1).

Volunteers were dressed in a selection of clothing representative of their operational areas. Five of the volunteers wore floatation devices, five did

not and had no other means of artificial buoyancy. During the in-water stage volunteers were requested to perform a number of physical and cognitive tasks and to report on their perceived wellness. Core body temperature and heart rate were recorded at regular intervals for all volunteers throughout the in-water and post casualty treatment stages by means of gastrointestinal radio pills and polar heart rate monitors.

Readers should note that an operational condition of this research was that at no time during the in-water stage would a volunteer's core body temperature be permitted to drop below 35°C. The core body temperature is generally accepted as signifying mild hypothermia. If this occurred the volunteer was to be immediately removed from the water and treated accordingly. This programme was not intended or designed to investigate the incapacitatory effects of hypothermia.



Photo 1. Floating/Pontoon dock area



Photo 2. Casualty treatment centre

Monitoring of Core Body Temperature.

In a clinical setting, such as an emergency room, the monitoring of core body temperature (CBT) is relatively straight forward using either rectal or oesophageal probes. In an outdoor setting, however, especially during water-based activities, the task of accurately measuring CBT is considerably more challenging. Two CBT monitoring methods were utilised during this research, i.e. gastrointestinal radio pills and tympanic membrane readings.

Gastrointestinal radio pill. This study employed the CorTemp gastrointestinal radio pill technology. The CorTemp is an ingestible core body temperature sensor (Figure 1) which wirelessly transmits core body temperature as it travels through the digestive tract. The sensor's signal passes through the body to the CorTemp Data Recorder (figure 4), in this case a hand held unit capable of recording the 10 volunteers core body temperatures. The sensor passes through the body at the subject's normal rate of motility which can vary anywhere from 24-36 hours. The CorTemp sensor is accurate to $\pm 0.1^{\circ}\text{C}$. The gastrointestinal radio pills were ingested by the volunteers >210 minutes before the start of the in-water phase to ensure that they were sited correctly. All sensors were checked prior to entry into the water and were found to be functional.

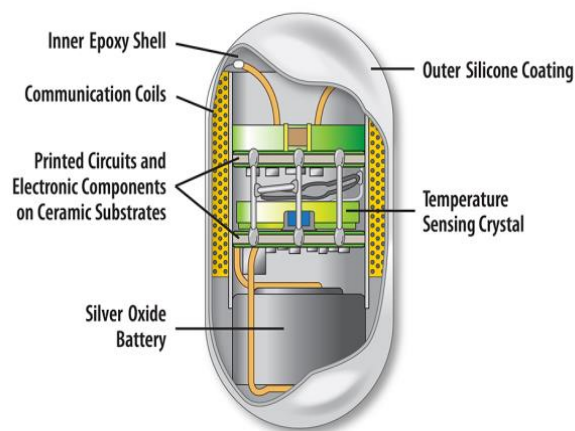


Figure 1. CorTemp sensor



Figure 2. CorTemp digital recorder

Tympanic Membrane Temperature Readings. Tympanic membrane temperatures were acquired using a Braun ThermoScan 5 tympanic thermometer during the post immersion treatment phase and compared with data from the CorTemp sensors. This device measures a person's temperature by remotely sensing the infrared radiation from the ear drum. It was not possible to use this device during the in-water phase due to the risk of water ingress into the unit. Note the unit is not waterproof. Tympanic membrane thermometers continue to be used, especially in search and rescue scenarios, to monitor casualty CBT's. While there is evidence that tympanic thermometers overestimate changes in CBT it was not the intention of this research to ascertain if the CBT differences between the two methodologies were consistent with the academic literature (Fulbrook, 1993; 1997; Robinson et al., 2008; Rogers et al., 2007; Summers, 1991).

Physical dexterity testing. At set intervals during the in-water phase the following tasks were undertaken by volunteers to ascertain changes in fine and gross motor skills:

- The ability to tie a bowline (knot) in a 50 cm piece of polypropylene rope
- The ability to touch the thumb to all four fingers of the same hand (both hands)
- The ability to open and deploy a pyrotechnic device (hand held rocket flare)
- The ability to turn on an ICOM hand held waterproof VHF radio and tune it to channel 68 and relay a message
- The ability to inflate a party balloon and tie a knot in the end so as to prevent the air escaping

Mental acuity. At set intervals during the in-water phase the following challenges were set for the volunteers:

- Recite their mobile telephone number backwards
- Remember facts from a simple story that they had read pre-immersion
- Recite the research date
- Solve a simple mathematical problem
- Spell out the name of one of the Navy ships using the phonetic alphabet

Wellness index. Wellness as it pertains to this research is defined as the quality or state of being healthy in body and mind. The volunteers, at regular intervals, were asked to respond to their perceived level of wellness. It was rated on a three-point scale:

- Point 1 – feeling well – no perceived adverse effects and enjoying the experience
- Point 2 – Feeling OK – some mild effects noted, only mildly enjoying the experience but feel like continuing
- Point 3 – Feeling decidedly unwell – does not wish to continue with trial

Swim test. During the in-water phase each volunteer was requested to swim 4 x 20 metre legs along the dockside, a total distance of 80 metres. The swim legs were undertaken by each volunteer at 3, 20, 30 and 50 minutes. Any stroke could be used and they could either lie on their front or back.

Research structure

The ten volunteers were randomly divided into two groups and numbered from 1 – 10. Each volunteer was marked with their allocated identification number on their forehead and on the back of both hands. A permanent marker was used for this task (see Figures 5 and 6 for examples).

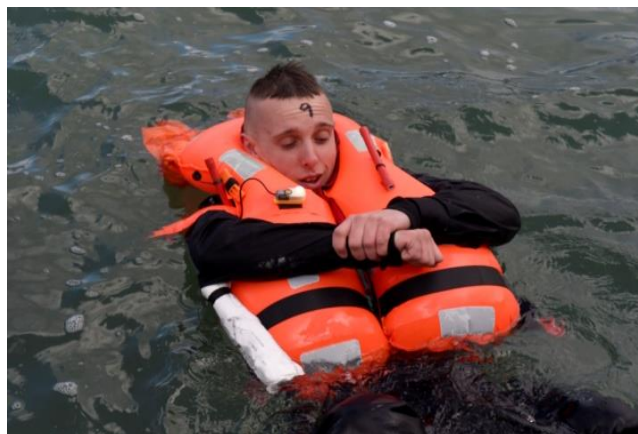


Photo 3. Volunteer after entering the water dressed in General Navy Duty Rig and wearing a life jacket. Note: volunteer's number on forehead for ease of recognition.



Photo 4. Volunteer about to enter the water. Note Navy diver chaperone and offshore safety RIB.

Each volunteer was assigned a set of clothing prior to entering the water. Some were assigned a PFD, others were not (Table 1).

| |
|--|
| Group One |
| 1 x test subject dressed in shorts and T Shirt – NO PFD (Personal floatation device) (volunteer 1) |
| 1 x test subject dressed in shorts and T Shirt - with NAVY issue PFD (volunteer 3) |
| 1 x test subject dressed in Once only Immersion Suit - with NAVY issue PFD (volunteer 5) |
| 1 x test subject dressed in Navy duty rig – NO PFD (volunteer 7) |
| 1 x test subject dressed in Navy duty rig – with Navy issue PFD (volunteer 9) |
| Group Two |
| 1 x Inland Fisheries Ireland (IFI) standard river patrol wear – NO PFD (volunteer 2) |
| 1 x IFI standard river patrol clothing – with 50N PFD as per IFI issue (volunteer 4) |
| 1 x standard NS issue Foul Weather Gear – NO PFD (volunteer 6) |
| 1 x casual day wear – jeans, shoes, vest, shirt, jumper, jacket – with 50N life jacket (volunteer 8) |
| 1 x Kayak Gear (IFI issue) – NO PFD (Standard kayak floatation aid) (volunteer 10) |

Table 1. Groups 1 and 2 clothing configurations plus presence or absence of PFD.

Both groups entered the water by jumping backwards from the pontoon. All experienced full immersion on entry (head submerged).

Summary of Immersion Results – IN WATER Phase

- 1 All volunteers exhibited some element of ‘cold shock response’ on entering the water (Photo 5).



Photo 5. Volunteer entering the water dressed in Navy Foul Weather Gear, no PFD. Note rapid inhalation of air and expression on face indicating cold water shock. Note also Navy diver as the in-water safety chaperone.

- 2 Nine out of the ten volunteers recorded an increase in respiration and heart rate after entering the water. Baseline data, including respiration rates, were acquired for all volunteers prior to entering the water.

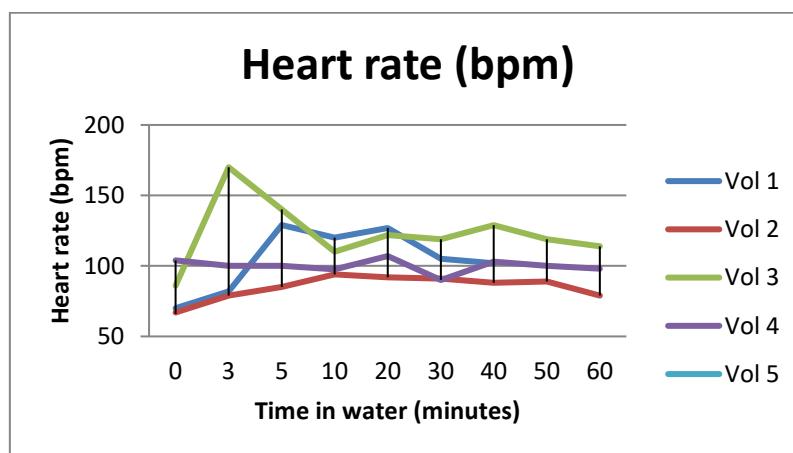


Figure 3. Heart rate (bpm) for volunteers 1 – 5.

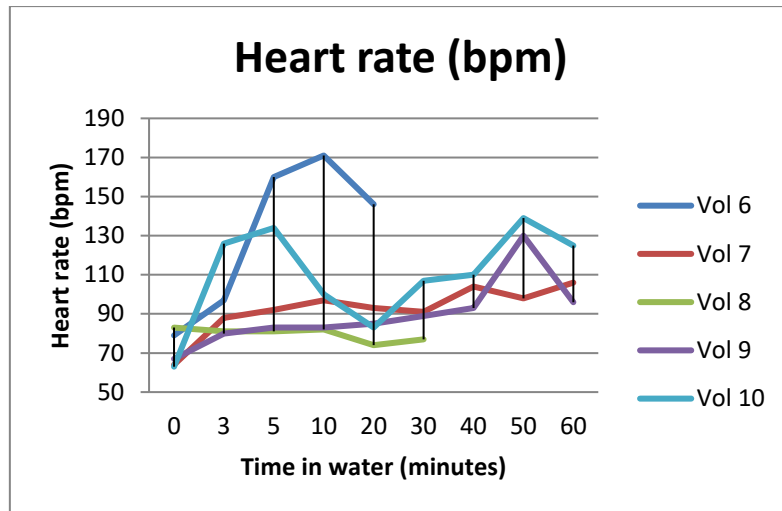


Figure 4. Heart rate (bpm) for volunteers 6 – 10.

- 3 Three volunteers exhibited a rapid 2 x times increase in their resting heart rate on immersion (Figures 3 & 4).
- 4 Rapid breathing (respiration rate) rates were noted in three volunteers (3,6,10) indicative of hyperventilation associated with ‘cold shock.’
- 5 The cold shock response was more pronounced for volunteers wearing minimal clothing.
- 6 All volunteers completed the manual dexterity tests (up to the time of premature exit or fully on 60 minutes) successfully even though some complained of feeling cold (wellness index 2).
- 7 Eight out of the ten volunteers completed the suite of mental acuity tests (up to the time of premature exit or fully on 60 minutes). Two volunteers failed on two questions however this is suspected to be a function of other factors rather than from the effects of cold incapacitation.
- 8 Seven out of the ten volunteers remained in the water for the full sixty minutes.
- 9 Three volunteers exited the water prematurely, two at their request, one upon instruction from research team.
- 10 No volunteer’s core body temperature dropped below 36°C during the immersion phase. The lowest core body temperature recorded for an in-water volunteer was 36.08°C.

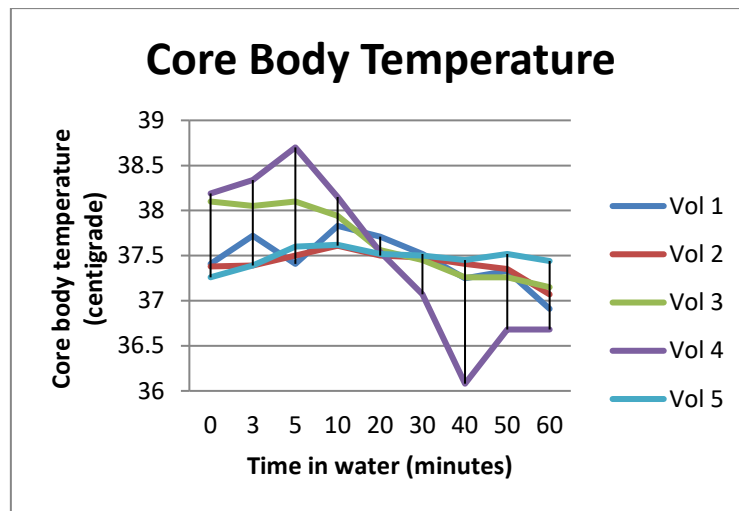


Figure 5. CBT for volunteers 1-5 – IN-WATER phase

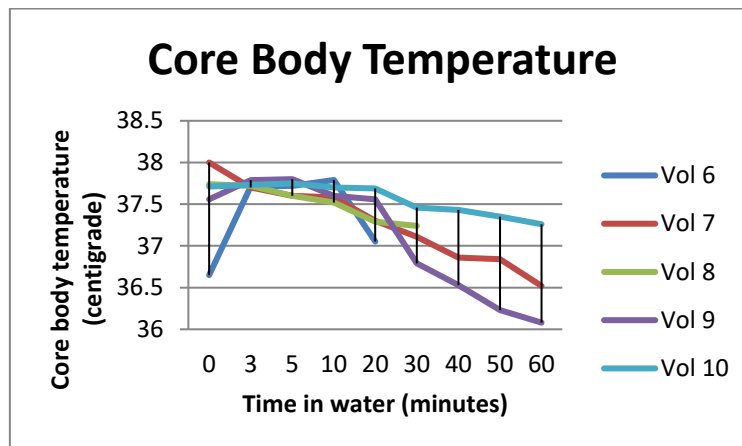


Figure 6. CBT for volunteers 6 - 10 – IN WATER phase

- 11 No volunteer was classified as hypothermic either in or on exiting the water.
- 12 During the swim legs all volunteers exhibited a visual decline in their swimming ability, determined by body position in the water.
- 13 The three volunteers who exited the water prematurely demonstrated a greatly reduced ability to swim or remain afloat.
- 14 All volunteers found exiting via the V Dock difficult to impossible. This is unsurprising for a number of reasons. First, it is probable that all were suffering a degree of muscular incapacitation, as evident from their decline in swimming ability. Second, the design of the V Dock and water depth would have prevented any leg purchase making extraction, at least in the initial stages dependent on sufficient upper body strength. Third, the weight of water in their clothing would have added a considerable extra

challenge to the task of self extraction. In addition, it is highly probable that all the volunteers were suffering from depleted energy reserves. The process of shivering, a defence mechanism to try and offset the cooling of the bodies CBT, depletes energy reserves.

- 15 Two volunteers who exited the water at 60 minutes via the pontoon ladder succeeded in exiting the water unaided.
- 16 One volunteer who exited the water prematurely through swim failure at 30 minutes did manage to exit the water via the dock ladder with assistance. This volunteer was wearing the Navy Foul Weather Gear.
- 17 Two of the three volunteers who prematurely exited the water were not wearing lifejackets and were finding it increasingly difficult to maintain a patent airway (keep their airway above the water). Further their wellness index was decreased on exit.
- 18 The one volunteer who was wearing a PFD and who prematurely exited on 30 minutes did so because of leg cramps.
- 19 Five volunteers reported debilitating leg cramps during the in-water phase.

Discussion

While the purpose of this research was to demonstrate, from an educational perspective, the effects of cold water immersion on the human body and on how to treat a casualty suffering from such effects, a number of outcomes were noted, both during the in-water and post immersion phases.

From the outset it is important to note that the prior medical screening of the volunteers, the relatively small sample size, the volunteer self-selection process itself and the level of support that each volunteer was afforded when in the water may all have had an impact, compounding or otherwise, on the results. While the degree of influence from these factors is not possible to determine there is certainly little doubt that much of the stress and anxiety associated with accidental immersion was removed, probably resulting in improved performance outcomes for the volunteers. Further as the volunteers willingly put themselves forward for selection, all would have felt comfortable that their welfare would be protected during the research and as such this most likely would have further reduced anxiety levels. In addition all stated that they were comfortable and confident in water.

Physical and psychological stresses have a considerable bearing on the outcome in a survival situation (Buck, 2015; Brieva, et al., 2005; Leach, 2011; Tipton, 1989). In-water-based scenarios it is no different. This applies not only to a casualty but also to the potential rescuers. Removal of these stressors, as part of the research process, will have a tendency to minimise

negative and compounding survival factors and to prolong casualty function and life. As a consequence the capabilities, state of mind, and performance of the volunteers throughout this research may well represent the most optimistic of outcomes.

The Effects of Cold Water Immersion

The body's response to cold water immersion can be classified into **four stages** - cold-shock response (**stage 1**), cold incapacitation (**stage 2**), hypothermia (**stage 3**) and circum rescue collapse (**stage 4**) including after-drop.

Cold Shock Response (stage 1). The cold shock response, which can and does result in fatalities, usually lasts from between 1-3 minutes after immersion in cold water. The degree to which it affects a casualty is dependent on a number of factors including the level of thermal protection that the casualty has on entering the water and on the amount of exposed skin. Other factors that influence the cold shock response are the rate at which the person enters the water, gradually to rapidly, and also whether the head is submerged on entry.

The primary danger from the cold shock response is the immediate risk of aspiration of fluid if the head is submerged during the gasp reflex. The gasp reflex is an involuntary action. Hyperventilation may result in unconsciousness leading to drowning if the casualty is not wearing a PFD. The consequential increased cardiac output may lead to cardiac arrest. Autonomic conflicts (sympathetic/parasympathetic conflict) may also result in cardiac arrest. It is estimated that 25% of people die in the first few minutes from cold shock (Buck, 2015).

Cold incapacitation (stage 2). Cold incapacitation usually occurs from between 10 to 30 minutes after immersion. Generally, the colder the water the quicker the onset. From a survival and self-rescue viewpoint the rapid loss of fine and gross motor skills, often recorded in relevant scientific literature to occur in the first 5 to 15 minutes, primarily in the hands and fingers, may pose serious challenges for self-rescue. The loss of power and muscle coordination (muscle incapacitation) may prevent the opening of survival equipment such as a flare, the attachment of a karabiner to a safety line, or simply climbing up a ladder or pulling oneself up a river bank. Swimming performance also declines rapidly even in fit young swimmers and complete swim failure is reported to be common.

Failure to initiate or achieve self-rescue at the earliest opportunity may result in death through drowning if a casualty is not wearing a PFD. The ability to remain afloat with the airway out of the water is seriously compromised with the onset of swim incapacitation.

The key factors that determine the rate of cooling for a person in cold water include:

- Age
- Gender
- Water temperature and water state
- Clothing at time of immersion
- Body mass to surface ratio
- Level of physical fitness
- Physical behaviour in the water
- Mental state – calm, stressed, panicked

Hypothermia (stage 3). While it is widely believed by a large cross section of water users and the public in general that the onset of hypothermia is rapid and occurs in minutes, this is incorrect. The onset of moderate to severe hypothermia in Irish waters will take well in excess of 30 minutes to occur for most individuals and potentially much longer even when water temperatures are at their annual lowest. Most cold water immersion casualties are far more likely to drown as a consequence of stages 1 and 2 rather than from the progressive cooling of their body's core temperature. Death from hypothermia may take in excess of 60 minutes even in the coldest of waters. Death is usually from cardio respiratory arrest (Brannigan, et al., 2009; McEwan, 2008).

Circum Rescue Collapse (stage 4). The importance of preventing Circum Rescue Collapse (CRC) cannot be overstated. Twenty percent of conscious and viable hypothermic casualties recovered from cold water reputedly die as a consequence of CRC either before, during, or after rescue (Golden et al., 1994; Golden & Tipton, 2002). The common causes of CRC are:

- Mental relaxation pre-, upon, or post-rescue
- Removal of the hydrostatic squeeze from immersion in water
- Rough handling by the rescue team
- Incorrect re-warming techniques
- Aspiration of fluids or chemicals
- Continued cooling of the CBT

Interestingly, no volunteer became hypothermic during the in-water phase of this project. In fact, all volunteers maintained a CBT above 36°C including the three individuals who exited the water prematurely. CBTs were noted to rise in 8 out of the 10 volunteers following immersion. Further, the volunteers had no obvious difficulty in carrying out either the dexterity or cognitive tests. While at sixty minutes all remaining volunteers were at 2 on the wellness index, none complained to be feeling particularly unwell.

It was noted that the swimming performance of all volunteers deteriorated over the sixty minutes and five openly complained of leg cramps. While all succeeded in carrying out tasks that required fine motor skills (i.e., a high degree of manual dexterity), their gross motor skills, primarily the larger muscle groups, visibly failed as did their swimming coordination and overall swimming performance.

It also was noted that the respiration rates for the volunteers not wearing a PFD were higher than for those who had artificial buoyancy. Loss of swimming coordination and performance was very evident in all the volunteers who remained in the water for sixty minutes. A consequence of this loss of swimming coordination on survival, especially in rougher sea states, would most likely be a reduction in survival times. The decline in swimming performance also was reported by Golden and Tipton (2002) in their research. Further, depending on the direction a swimmer would have to swim (into, with, or side on to the wave action) also had an impact on survival times. It is probable, based on visual observations in the latter part of the in-water stage of this study, that many of the volunteers would have found it increasingly more difficult to make headway had the water conditions been more challenging.

It was also noted that all volunteers tended to favour breaststroke or swim on their back as the study progressed. Their speed through the water noticeably declined, a consequence of their poor body position in the water (more vertical/less streamlined), decreased energy supplies, and growing lethargy. This loss of swimming skill level certainly merits additional research as the psychological effects of losing control or losing the capacity to swim to rescue or a place of refuge may well have a compounding effect. Certainly psychological as well as physiological effects would appear to be the case in accidental immersion scenarios (Brannigan, et al., 2009; Brieva, et al., 2005).

Volunteers not wearing a life jacket or PFD were noted to be working progressively harder to stay afloat over the duration of the in-water phase. Volunteers with a floatation device, while not having to work to keep their airway intact, also exhibited a decline in swimming performance and a general water competence. All appeared to exhibit a growing level of lethargy as the research continued to conclusion.

Interestingly in both groups dialogue and human interaction between volunteers and shore personnel declined markedly over the duration of the in-water phase. While initially most of the volunteers were partaking in light banter, this decreased, for some to the extent that communication did not occur unless they were asked a direct question. This potentially has consequences for survival, especially in group settings where it is the actions of the group, collectively working together, that produces a dynamic for survival. This area

deserves investigation especially in multi casualty situations, such as an overturned boat or liferaft, where all parties must work together to ensure a successful outcome.

It would appear, from visual observation, that most, if not all volunteers, would have found it difficult to stay afloat in an open water scenario in excess of sixty minutes without a PFD. The outcome of course would be that they would have drowned as their airway became compromised and they aspirated water. While the sea conditions in this study were calm, had they been otherwise, the coordination of breathing with wavelet activity may well have proved challenging for some, especially for those individuals not wearing a PFD. It was very evident that the mouths of the volunteers not wearing a PFD became progressively closer to the water's surface as they tired. In fact three of the volunteers not wearing PFD's were actively flushing their mouths with sea water.

It should be noted that wearing a PFD does not necessarily ensure that a casualty will not drown. As the performance of the casualty to orient themselves so that their back is to the oncoming wave trains declines, the possibility of aspirating water increases. Increased respiration rates compound this challenge. Unconscious casualties would, by physical hydrodynamic processes, orientate themselves face forward to the oncoming wave trains. Even conscious but exhausted casualties may find that they simply don't have enough energy to prevent this occurring.

The consequence, for the conscious casualty, is that they must now coordinate their breathing to correspond with the wave troughs to prevent inhalation of water. The unconscious casualty would literally be at the mercy of the waves and over time would most probably aspirate water and drown. The very evident loss of strength and coordination of the volunteers towards the end of the study would indicate that had the waters been rough or choppy then they would have similarly faced these challenges. Many modern lifejackets are fitted with a drawdown spray hood to protect the casualty's face and airway from spray and foam and to prevent accidental aspiration of water. While these do offer a level of protection little applied research has been conducted on their efficacy for the unconscious casualty in different sea conditions.

It is important to highlight that the challenge of maintaining a patent airway for the volunteers was not due to hypothermia but from cold water incapacitation and muscular exhaustion. Cold water incapacitation leading to drowning rather than from hypothermia would have been primary cause of death. Cold incapacitation of the large muscle groups, loss of gross motor skills, and an overall chilling of the peripheral shell, rather than loss of the fine

motor skills, appears to be the dominant factor determining survival for the volunteers in this study.

While it is encouraging to note that mentally and physically all volunteers were able to summon help by broadcasting on a marine band VHF radio, the challenge of staying afloat without a PFD may well have proved to be the determining factor in their survival when awaiting rescue. Another aspect that deserves consideration is the apparent positive state of mind and low stress levels exhibited by all volunteers when entering the water. Most remained calm throughout the sixty minutes of immersion and even two of the three volunteers that exited the water prematurely did not appear to be unduly stressed or anxious. We consider the positive outlook was the result of several factors including;

- medical screening of volunteers
- voluntary selection process
- pre-briefing
- the presence of onsite medics
- the hands-on chaperoning by navy divers (each volunteer when in the water had a qualified navy diver with them at all times)
- the controlled environment

Volunteer (#6) wearing the NS Foul Weather Gear without the PFD (Photo 5) did exit the water after thirty minutes, claiming that he felt he could no longer remain afloat. On interview later he stated that he ‘couldn’t stay up any longer.’

This was interesting because, although his clothes were no doubt saturated with sea water they would not have had a large bearing on his buoyancy in the water as his clothes were only marginally negatively buoyant. What may have occurred, mostly through either movement of the individual or movement of the surrounding water, was that the air trapped in or around an individual’s clothing was disturbed and escaped. This may have resulted in the perception of the loss of buoyancy and often has been misinterpreted by an individual that their clothes are ‘pulling them down.’ Depleted energy reserves may compound this perception. Unfortunately, in real life field conditions, this often results in an individual removing their clothing in the water which results in accelerated core body heat loss. Simply stated, in cold conditions the more layers a person has on in the water, the better their thermal insulation.

It was reported that volunteer (#6) indicated his concerns to the Officer in Charge on a number of occasions. At thirty minutes volunteer (#6) swam to the pontoon ladder and exited without help. It is important to note that he did not exhibit any inability to carry out the cognitive reasoning or physical task during the in-water stage. His swimming technique and body position in the

water were not noticeably different from the other volunteers when conducting the swim legs.

From a group survival perspective volunteer #6's unannounced and rapid exit from the water would present a challenge for a team leader in a real life survival situation. Key to a positive group survival dynamic is recognising those individuals who require additional supports. As there were no obvious visual indicators that volunteer (#6) was experiencing difficulty in remaining afloat consideration should be given to designing systems that can identify such occurrences.

In support of this observation Golden (2002) reported that an event occurred during an English Channel swim where a female swimmer after approximately six hours was noted to be in difficulty. She was immediately retrieved by the safety boat which was only a couple of metres away but could not be revived. It was reported by the safety boat that there was no obvious signs that she was in trouble prior to her extraction (Golden, 2002; Robinson, et al., 2008).

In real life accidental immersion scenarios acute stress shifts the brain into a state that promotes the adoption of defence mechanisms. A consequence of which is that the sympathetic nervous system overrides all other functions promoting a flight or fight response as the body triggers the release of noradrenaline and adrenaline (Leach, 2004). While this initially has potential benefits because one may escape the immediate threat, providing that the correct escape route is selected, it does nevertheless have long term survival consequences in the form of sustainability. In short, the person likely runs out of energy thereby quickly limiting downstream options (Currai & Symington, 1995; Golden, 2002; Giesbrecht, 2000).

Stress is well documented as having a significant negative effect on survival (Ansell, 2008). While previously stated there are initial survival benefits, over time, especially if rescue or self-rescue does not occur, they can be, and often are, physically debilitating and fatal (FEMA (2015)), Turner & Engle, 1989). One key element of stress is the rapid loss of strength and energy over time (Leach, 2011). Good judgement and the ability to make correct lifesaving decisions are another.

While it is not possible to draw definitive conclusions regarding the impacts of stress in real life scenarios from this study due to its tight controls, level of volunteer protection and small cohort size, it is certainly an area that merits further investigation. The interesting observations from volunteer #6 may indicate that even in a controlled setting the sympathetic nervous system plays a part in one's survival irrespective of what supports are in place (Paton, 1994).

Volunteer Extraction Phase (Exiting the Water). All volunteers were requested to exit the water without assistance via the floating and anchored v-dock or by the pontoon ladder. Three volunteers exited the water by means of the pontoon ladder, seven by way of the v-dock. Of the volunteers who attempted exit via the floating v-dock, three succeeded in exiting unaided and four required full assistance. It should be noted that exiting via the v-dock is difficult due to the considerable upper body strength required.

The volunteer in the NS Once Only Survival Suit (volunteer 5) walked to the boat house treatment centre unaided. The other nine volunteers were packaged by the NS medical support team. All nine volunteers were packaged in wind and waterproof survival blankets on exit and stretchered to the boat house treatment centre. All remained in a horizontal position throughout. All volunteers complained of cold on exit including the volunteer wearing the NS Once Only Survival suit. Nine of the volunteers stated that they had some level of cold incapacitation. No volunteer had an initial CBT below 36° C when exiting the water (Figure 7).

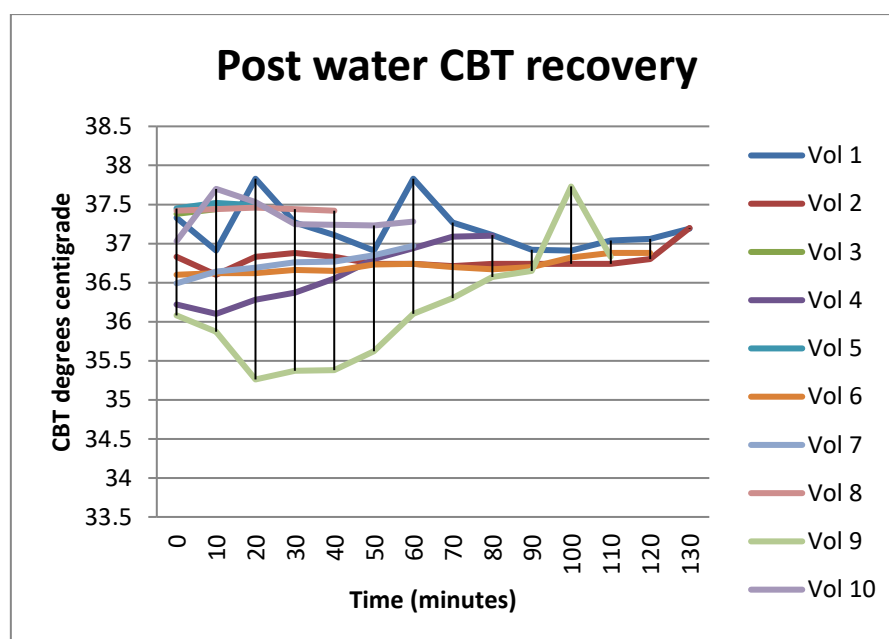


Figure 7. Change in CBT for each volunteer when in treatment centre. A key observation is that all volunteers, excluding the volunteer wearing the NS Once Only Survival Suit demonstrated varying levels of cold water incapacitation.

Another is that all four volunteers who were unable to exit the v-dock unaided also appeared to lack coordination. Such findings have been noted by other authors in similar work (Golden, 1973; Paton, 1994; Webb,

1985). Further research would be beneficial in exploring this area as it potentially has consequences for solo survival situations.

Boat House Casualty Care

On arrival at the treatment centre the medical team instructed the volunteers to remove all their wet clothing and the volunteers were assisted where required. The volunteers were then patted dry and dressed in dry clothing. They were then packaged in thermal wraps and blankets. Their CBT's were monitored during this stage. The medical team were instructed to ensure that all volunteers remained relatively static during the process (Photo 6).



Photo 6. Packaging system deployed in recovery centre. Note blue chemical heat blanket.

The packaging system employed was as follows:

1. Blizzard thermal blanket base layer
2. Plastic barrier sheeting
3. Chemical heat packs at groin, underarms, neck and chest
4. Blanket/s
5. Blizzard blanket then folded over and around cocooning blanket and heat packs.
6. Additional blankets as required

The thermal wrap deployed was the Blizzard triple layer survival blanket. The volunteers CBT's were monitored throughout this process (figure 12). Volunteers were offered warm sweet tea or a warm chocolate drink.

Core Body Temperature (CBT) Results

Key findings from the post immersion treatment stage included that the CBT's of eight of the ten volunteers continued to drop in recovery. All volunteers were at one stage colder in recovery than they were in the water. The

volunteer wearing the NS Once Only Survival Suit complained of feeling cold when out of the water but not in the water. The CBTs of all the volunteers were slow to increase to baseline, one in excess of 160 minutes, 4 in excess of 60 minutes and all in excess of 30 minutes (Figure 7). Figure 18 graphs the degree of change from initial CBT to lowest CBT for each volunteer.

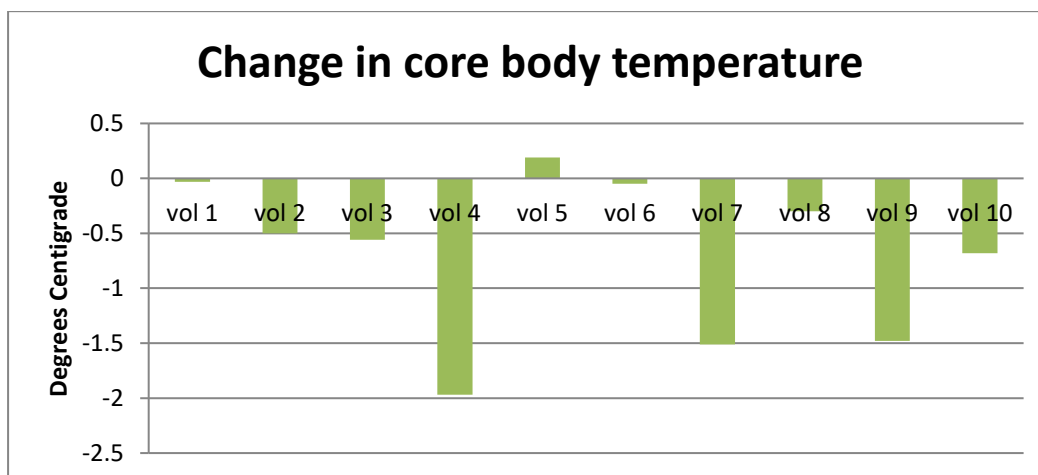


Figure 8. Degree of CBT change for each volunteer over the duration of the research (both in-water and treatment phases)

Six out of the ten volunteer's experienced discomfort and leg cramps during the rewarming stage. The tympanic thermometer in all cases, during the post immersion treatment phase recorded a temperature circa 1.0 °C lower than the CoreTemp radio pill. This is an interesting finding and has relevance and significance for field/remote casualty care incidents using such devices. While all volunteers stated that they were cold in recovery volunteer (#2) demonstrated a serious decline in her ability to function (complete simple manual tasks, undressing etc.).



Photo 7. Volunteer 2 demonstrated a significant decline in her wellness index (3) when out of the water and an inability to carry out simple tasks during recovery.

Volunteer #2's wellness index declined rapidly after exiting the water. Her CBT at time of water exit was 37.07°C, clinically normothermic and declined to, at its lowest point, 36.62°C. Note that at no stage was she clinically hypothermic; however, she complained that she felt unwell and exhibited signs supporting this, mainly intense shivering. 'Afterdrop' is a well-documented consequence after rescue. Continuing casualty decline during the post-exit stage has been reported previously (Golden, 1973; Golden, et al., 1994; McEwan, 2008). Circum Rescue Collapse and afterdrop are reported to account for 25% of immersion fatalities (Golden & Tipton, 2002).

What is striking about the case of volunteer #2 is that during the immersion phase she was one of the most alert volunteers and was able to pull herself onto the dock. In a matter of minutes, however, volunteer #2 started to exhibit signs of incapacitation and would not, in the opinion of the authors, have been capable of functioning in a way to ensure her survival. Without the assistance provided, it is unlikely that she would have been able to undertake simple survival tasks such as removing her wet clothing, finding shelter, or rewarming/dressing. While volunteer #2's survival post exit performances were not investigated in this study, nor indeed were those of any of the program participants such further study may well be beneficial in the design of survival protocols. Certainly from an educational perspective, observers were surprised by both the level of incapacitation and its duration for volunteer #2. Although often overlooked and underestimated, post-extraction casualty care is fundamental in ensuring a positive outcome (Buck, 2015; Giesbrecht, et al., 1997).

Conclusions and Future Research

The ability of all volunteers to maintain functional levels of manual dexterity at water temperatures previously reported by many researchers to seriously impact dextrous abilities, requires additional research. The authors believe this finding was significant and certainly deserves further exploration because it was inconsistent with previous research. It should be noted that even the volunteers who exited the water prematurely demonstrated adequate functional fine motor skills. Also, there was no apparent decline in cognitive function for any of the volunteers over the in-water phase. Unfortunately, cognitive function tests were not run during recovery which need to be further studied.

Decline in swimming performance (i.e., gross motor function) was noted in all volunteers during the in-water phase of the project. This loss was consistent with the literature and emphasized the importance of wearing a PFD (Keating, et al., 1969). The increase in respiration and heart rates of all volunteers as they entered the water likewise was consistent with the existing literature. The CBTs maintained by all volunteers over the 60 minute in-water period clearly indicated that complications associated with hypothermia are not necessarily a priority in water temperatures above 10°C for most healthy adults. While the sample size lacks sufficient statistical power and confidence other research has concurred with this observation (Giesbrecht, et al., 1997).

The degree or level of incapacitation experienced by volunteers during the casualty care phase of this research was not reflected by significant changes in their CBTs. Many of the volunteers experienced debilitating cold incapacitation which in the opinion of the authors would have had consequences for survival in an unmonitored situation, but only exhibited small CBT changes. It is therefore important that consideration be given to the temperature differential between the peripheral shell and CBT when treating a CWI casualty. Cold water shock and cold water incapacitation were noted to be far more likely to compromise the volunteers chances of survival over the 60 minute in-water phase.

Post in-water casualty care was noted to be complex and individual specific. While treatment regimes applied were similar, individuals responded differently. A person suffering adversely from the effects of cold water immersion on exit might find undertaking basic rewarming protocols difficult to impossible to accomplish in real life situations.

Raising a volunteer's CBT through the procedures deployed in this project was noted to take considerably more time than was expected by the observers. Importantly, the procedures (e.g., thermal wrap) were found to be effective. Further the continued CBT drop for all volunteers post water exit has generated considerable discussion regarding the physiological mechanisms responsible. In addition, the level and degree of care required to manage

casualties post immersion was noted to be resource heavy. This may well have field implications, especially in operational settings or where there are mass casualty scenarios.

Additional research should to be considered in the area of casualty retrieval both to boat and shore. This would be particularly relevant for casualties who have prolonged exposure times, are unresponsive in the water, or who have been exposed to sub-10°C waters.

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Appendix 1. Weather conditions Cork Airport – 19th May 2015**Reports from Cork Airport**

| Date | Rainfall (mm) | Max Temp (°C) | Min Temp (°C) | Grass Min Temp (°C) | Ave Wind Speed (knots) | Max Gust (if >= 34 knots) | Sunshine (hours) |
|-----------|------------------|---------------------|---------------------|---------------------------|------------------------------|---------------------------------|---------------------|
| 19/5/2015 | 2.2 | 11.7 | 5.1 | 2.4 | 14.6 | | 7.9 |

